

Hypomagnesaemia in Beef Cows Wintered in Ontario

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ABSTRACT

A field experiment was undertaken in northern Ontario in order to assess the magnesium status of beef cattle raised in the area. Magnesium status was assessed using several criteria including blood and urine magnesium levels, and bone biopsy samples. Eighteen groups each containing four pregnant Shorthorn beef cows were used. Each of the following three mineral feeds were offered to six groups throughout the experiment: a mineral feed without magnesium, a mineral feed containing 8% magnesium in the form of magnesium oxide and the third containing sequestered magnesium with a magnesium level of about a tenth of that in the mineral feed containing magnesium oxide. During the winter, when the cows were housed indoors, they were fed grass silage. Six groups, two on each mineral feed, remained indoors throughout the summer. The other 12 groups were turned out to pasture on May 25 and continued receiving the appropriate mineral feed. There were no differences in serum magnesium owing to magnesium-supplementation treatments observed at any time during the experiment. Serum magnesium levels fell drastically in all groups before the cows were released to pasture, implying that the hypomagnesaemic condition was attributable to the stress of yarding. The

rate of recovery from hypomagnesaemia was slower in the cows released to pasture than in those kept indoors. Urine samples from cows returned to the pasture were indicative of low magnesium status. At the end of the experiment, the magnesium levels in the bones of the housed animals were higher than for those on pasture. In spite of severe cases of hypomagnesaemia, no clinical signs of this metabolic condition were observed.

RÉSUMÉ

Cette expérience visait à déterminer l'état du magnésium, chez des vaches à boeuf élevées dans le nord de l'Ontario. Les auteurs choisirent à cette fin 18 groupes de quatre vaches Shorthorn gravides et ils utilisèrent plusieurs paramètres, entre autres la magnésémie, la magnésurie et la biopsie osseuse. Tout au long de l'expérience, ils servirent à six des 18 groupes, l'un ou l'autre des trois suppléments minéraux suivants: un supplément dépourvu de magnésium; un autre qui en contenait 8%, sous la forme d'oxyde de magnésium; un autre qui n'en contenait que 0.8%, sous la forme de l'élément magnésium. Au cours de leur hivernage dans l'étable, les vaches reçurent de l'ensilage de foin. Six groupes, dont deux recevaient chacun l'un ou l'autre des trois suppléments minéraux, passèrent l'été

dans l'étable. On envoya les 12 autres groupes au pâturage, le 25 mai, et on continua à leur donner leur supplément minéral approprié. À aucun moment de l'expérience n'enregistra-t-on une différence dans la teneur sérique en magnésium, imputable à la composition des suppléments minéraux. Cette teneur baissa toutefois de façon drastique, dans tous les groupes, avant qu'on les envoie au pâturage, indice que l'hypomagnésémie était attribuable au stress du confinement. Les vaches envoyées au pâturage se remirent plus lentement de l'hypomagnésémie que celles qui passèrent l'été dans l'étable. L'analyse des échantillons d'urine des premières révéla une faible quantité de magnésium dans leur organisme. À la fin de l'expérience, la teneur des os en magnésium s'avéra plus élevée chez les vaches gardées dans l'étable que chez celles qui étaient au pâturage. En dépit de cas d'hypomagnésémie marquée, on n'observa pas de signes cliniques de cette condition métabolique.

INTRODUCTION

Few detailed reports are available on hypomagnesaemia in beef cows in Ontario, although the disorder is an important metabolic disease in cattle. Field and experimental observations (Hidirolou, unpublished data) have indicated incidence of hypomagnesaemia in

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beef cattle in the areas of northern Ontario and northwestern Quebec. These observations were supported by the findings of Fisher *et al* (13) who reported serum magnesium (Mg) concentrations in the Kapuskasing Experimental Farm beef herd to be lower than the accepted normal levels of 18-32 mg/L (22). These workers also reported several cases of grass tetany following parturition which responded to Mg therapy.

The field study reported herein was carried out at the Kapuskasing Experimental Farm to determine the extent of this hypomagnesaemic condition and whether or not the incidence of hypomagnesaemia could be influenced by the type of Mg supplementation, housing and pasture, the latter with two different levels of nitrogen fertilization.

MATERIALS AND METHODS

ANIMALS AND DIETS

Seventy-two Shorthorn cows artificially bred with Hereford semen to calve from mid-March to May, were randomly allocated to 18 groups of four cows. Starting in December they were wintered in an enclosed, insulated, unheated barn with each group penned separately. Each of three mineral feeds were provided on a free choice basis, to six of the 18 groups. One mineral feed contained no Mg, one contained 8% Mg in the form of magnesium oxide and the third contained sequestered Mg.¹ The latter mineral feed contained about 0.8% Mg. The composition of the mineral feeds and their Mg contents (by calculation) are shown in Table I. The minerals were fed in the conventional type of covered containers.

Until March 1, each group received formic acid treated grass silage at the rate of 1.2 kg DM/100 kg initial body weight and from March 1 until the end of winter feeding on May 25, it was fed *ad libitum*.

TABLE I. Composition of the Mineral Feeds (% w/w)

	Control	Magnesium Oxide	Sequestered Magnesium
Dicalcium phosphate	35	35	35
Cobalt-iodized salt	60.5	45.5	49.5
Vitamin A and D ^a	4	4	4
CuSO ₄ ·5H ₂ O	0.5	0.5	0.5
Sequestered magnesium (7.3% Mg)	—	—	11
Magnesium oxide (60.3% Mg)	—	13.3	—
Magnesium (%)	0	8.0	0.8
(by calculation)			

^a8.8 x 10⁶ IU vitamin A and 8.8 x 10⁶ IU vitamin D per kg

Six groups of four cows, two groups on each mineral feed, remained indoors throughout the summer; the other 12 groups were released to pasture on May 25. The 24 animals remaining indoors continued to receive the formic acid treated silage *ad libitum* and the appropriate mineral feed. Four pastures were used during the summer, two receiving 78 kg/N/ha and the other two 155 kg/N/ha which was applied in the early spring. In order to continue supplying the animals with the appropriate mineral feeds, each pasture was subdivided into three equal sections, each provided with one of these feeds *ad libitum*. Three groups, one on each feed, were then randomly allocated to each pasture. The cows continued to nurse their calves until fall weaning.

SAMPLING AND CHEMICAL ANALYSES

Blood serum was obtained from all cows and calves according to the schedule shown in Table II.

Bone samples were taken from two cows in each subgroup at the beginning and the end of the experiment. The bone biopsy was performed with a 3 mm trephine on the ninth rib, 20 cm above the costochondral junction. A local anesthetic infiltration and aseptic surgical technique was used throughout. Samples of urine were also obtained from these cows at the beginning of the experiment and at 14 ± 3 days after calving. In collecting the urine samples, the cow was held in a stanchion stall and an indwelling urethral catheter² was put in place. Collection continued from 16.00 h until 8.30 h the next morning. In addition, in the spring, 24 h total urinary collections were taken twice from five cows in the control group. This was done 48 h before they were turned out onto pasture and three days after being on lush grass.

The serum magnesium estimation was performed using a Perkin-Elmer atomic absorption Spectrophotometer, model 460,

TABLE II. Calendar of Sampling

	Date	Serum	Cow Urine	Bone	Calf Serum
January	Jan. 5	x	x	x	—
Mid-winter	Feb. 5	x	—	—	—
48 hours after calving	ca. Apr. 15	—	—	—	x
2 weeks after calving	ca. Apr. 30	x	x	—	—
24 hours before pasture	May 24	x	— ^a	—	x
72 hours after pasture	May 28	x	— ^a	—	x
10 days after pasture	June 4	x	—	—	x
17 days after pasture	June 11	x	—	—	x
24 days after pasture	June 18	x	—	—	x
September	Sept. 21	x	—	—	x
November	Nov. 30	—	—	x	—

^aSample taken from five cows

¹Sequestramin magnesium, Stauffer Chemical Company, Westport, Connecticut.

²White Cross Surgical Supply Ltd., Ottawa, Ontario.

using dilution of 1 in 50 with deionized water. Magnesium analysis of urine was performed on digests prepared by taking urine samples to dryness on a water-bath followed by ashing at 450° for 16 h. The residue was warmed gently with 6M-HCl until solution was complete and after appropriate dilution, urine samples were analyzed by atomic absorption for Mg concentration. After wet digestion, bone samples were also diluted and analyzed for Mg by atomic absorption spectrophotometry.

STATISTICAL ANALYSES

Analyses of variance were applied to the data for both cows and calves at each time period. Because the experimental structure changed on the pasturing date with the introduction of the housing treatment, the appropriate analyses of variance changed. However, the housing term and the housing x diet interaction were included throughout in order (a) to provide a test of the random allocation of animals to housing treatment and (b) to provide an indication of the consistency of the means of the housing groups before the pasturing date. Although the experimental design might suggest a split-plot structure with diet supplements within housing treatments and animals within pens, the three error terms were consist-

ently of the same magnitude and hence they were pooled.

Partial correlations were calculated both between the same measurements at different time periods and between different measurements at the same time period. All correlations were conditional on diet, housing and the diet x housing interaction.

RESULTS

Providing magnesium in the mineral feeds, either as sequestered magnesium or as magnesium oxide, did not prevent or even alleviate hypomagnesaemia.

Table III gives the serum means of cows and calves for each method of housing during the summer, that is, in the barn or outdoors on pastures fertilized with 78 kg or 155 kg N/ha. There was an extreme drop in Mg concentration in the cows' serum samples taken 24 hours before going to pasture. After 17 days on pasture serum Mg concentration returned to normal levels. The rate of recovery appeared to be related to method of confinement, with animals kept indoors showing the most rapid improvement and the animals outdoors on the 78 kg N/ha the slowest. Differences between indoor confinement and outdoor were highly significant ($P < 0.001$) at

both 72 hours and ten days after pasture. At ten days after pasture, there was a significant difference ($P < 0.05$) between the means for the two pastures. By September, the levels of serum Mg had dropped considerably in the cows on pasture so that the differences among housing were again highly significant ($P < 0.01$).

The Mg serum levels in the calves (Table III) showed a marked drop near the time the animals were put to pasture, not unlike the pattern observed with cows. However, there were several apparent differences between the patterns of the cows and calves. The Mg concentrations of the calves appeared to reach their lowest points between three and ten days after pasture, somewhat later than those of the cows. Furthermore, unlike the Mg levels of the cows, the Mg levels of the calves continued to increase throughout the remainder of the experiment. The differences between the barn and the pastures, once established at ten days after pasture, were highly significant throughout ($P < 0.0001$). There was also evidence of differences between the two pastures, the differences being highly significant ($P < 0.01$) at ten days after pasture and in September, and significant ($P < 0.05$) at 17 days after pasture.

At the end of the experiment in

TABLE III. Magnesium Concentration (mg/L) in Serum of Cows and Calves

	January	February	Date of Measurement						Sept.
			14 days post-calving	24 hours pre-pasture	72 hours post-pasture	10 days post-pasture	17 days post-pasture	24 days post-pasture	
Cows									
Barn	21.174	20.07	22.41	13.09	18.06	21.13	21.49	16.98	17.83
Pasture 1 (78 kg N/ha)	20.99	19.15	21.82	11.43	11.96	16.60	18.85	17.08	14.47
Pasture 2 (155 kg N/ha)	21.73	20.10	23.23	12.72	11.72	19.55	19.43	17.07	15.33
S.E.M.	0.41	0.25	0.57	0.53	0.80	0.58	0.68	0.58	0.62
Significance test ^a					***	***	*		**
		48 hours postcalving							
Calves									
Barn		22.00		17.78	16.54	17.20	20.05	20.86	22.68
Pasture 1		21.34		18.60	14.52	13.92	15.02	17.37	18.48
Pasture 2		21.71		18.66	15.65	15.32	17.74	18.75	20.15
S.E.M.		0.49		0.48	0.41	0.49	0.54	0.55	0.34
Significance test ^a					**	***	***	**	***

^aF-ratio for housing differences:

*($P \leq 0.05$) significance level

**($P \leq 0.01$) significance level

***($P \leq 0.001$) significance level

November the Mg levels of the bones of the housed animals was significantly higher ($P < 0.05$) than for those on pasture (Table IV). The Mg concentration in the urine dropped considerably between January and 14 days after calving. Urine samples were taken from five cows in the control group 24 h before and 72 h after they went to pasture (Table V). The results showed an extreme fall in the urine Mg levels, much like that observed in the serum of the cows 24 hours before going out to pasture. Total 24 h urinary Mg excretion amounted to 0.37 ± 0.27 mg on pasture whereas it amounted to 2.3 ± 0.17 mg before pasture. This would indicate a conservation mechanism for tissual Mg. The partial correlations among Mg levels in the serum of the cows and calves at different dates are shown in Table VI. The correlations for the cows data were consistently low, the only exception being a correlation of 0.605 between ten days and 17 days postpasture. The data from the calves, on the other hand, showed high correlations between all measurements during the first 24 days of pasture, the highest being 0.835 between the 17 day and 24 day measurements. Correlations between the Mg levels of the cow and calf at the same date were low throughout.

The partial correlations of urine and bone measurements from the cows at different dates (Table VII) were much higher than those of serum: 0.629 between measurements of urine concentration in January and 14 days postcalving,

and 0.686 between Mg levels of bone in January and November. None of the correlations between measurements of serum, urine and bone at (or near) the same data

were very large, the highest being 0.492 and 0.526 between serum and bone measurements at the beginning and the end of the experiment, respectively.

TABLE IV. Magnesium Concentration in Urine (ppm) and Percentage in Magnesium of Oven-dry, Fat-free Bones of Cows

	Urine		Bone Biopsy	
	January	14 days postcalving	January	November
Barn	394.1	269.8	0.252	0.293
Pasture 1	432.7	224.1	0.242	0.263
Pasture 2	434.8	256.3	0.266	0.272
S.E.M. ^a	38.4	29.6	0.009	0.010

^aStandard error of mean. Approximate only because of slight difference in numbers on each housing method

* $P < 0.05$

TABLE V. Magnesium Concentration in Urine (ppm) and Serum (mg/L) of Five Cows

Cow	January		14 hours postcalving		24 hours prepasture		72 hours postpasture	
	Urine	Serum	Urine	Serum	Urine	Serum	Urine	Serum
1	509	21.4	305	23.7	389	14.3	29	13.4
2	434	20.8	168	23.1	344	10.2	144	18.8
3	384	23.3	116	17.8	167	10.9	1	10.4
4	420	22.9	444	—	300	12.8	6	12.8
5	510	23.1	320	25.0	133	10.8	1	8.4

TABLE VI. Partial^a Correlations among Mg Levels in Serum of Cows and Calves at Different Dates

Date	Cow Correlation with previous date	Correlation between cow and calf	Calf Correlation with previous date
February	0.241	—	—
14 days postcalving ^b	0.241	-0.065	—
24 hours prepasture	0.107	0.001	-0.049
72 hours prepasture	0.379	-0.007	0.545
10 days postpasture	0.061	-0.228	0.587
17 days postpasture	0.605	-0.288	0.701
24 days postpasture	0.156	-0.003	0.835
September	0.148	-0.027	0.152

^aCorrelations adjusted for diet, housing and diet \times housing interaction

^bFor calf, this measurement was taken 48 hours postcalving

TABLE VII. Partial Correlations^a among Plasma, Urine and Bone Levels of Mg at Different Dates

i) Urine	Bone ^b	Serum ^b	Conc.	Urine	
				January	14 days postcalving
Jan. conc.	-0.136	0.030	—	Total	Conc.
total	0.233	-0.023	0.536	—	Total
14 day conc.	— ^c	0.425	0.629	0.217	—
total	— ^c	0.522	0.475	0.282	0.553
ii) Bone biopsy	Serum ^b	Urine (conc) ^b		Bone	
				January	November
January	0.492	-0.136	—	—	—
November	0.526	— ^c	0.686	—	—

^aCorrelations adjusted for diet, housing and diet \times housing interaction

^bCorrelation between two sources, e.g. urine, taken at (or near) the same time

^cThere was no bone biopsy near the date of the urine sample 14 days after calving

DISCUSSION

EXTENT OF THE HYPO-MAGNESAEMIA IN COWS

The levels of Mg in the sera of the cows, measured in January, February and 14 days after calving (March or April), were above 20 mg/L which could be considered normal for cattle (21). By 24 h before the animals were turned out to lush spring pasture, serum Mg levels had dropped drastically, reaching levels as low as 6.1 mg/L. There was no evidence found of difference due to dietary supplements. These results are in agreement with those reported by Allcroft and Green (2) and Allcroft (3) who reported that magnesium supplementation offered as a mineral mixture failed to maintain normal serum level in cattle and was not even effective in restoring a falling seasonal blood value to normal level. Allcroft and Burns (5) reported that a number of nutritional, physiological and environmental factors are implicated in the occurrence of hypomagnesaemic condition; the drop may have been related to the stress caused by yarding the animals before going to lush grass, especially because the animals were at peak lactation and the Mg requirement can be twice that of a nonlactating cow (1). Herd *et al* (15) observed that stress factors such as agitation during yarding and handling could trigger hypomagnesaemia. The authors suggest that the disorder in lactating cows observed a day before going out to spring pasture was due to multiple interrelated causes. The stress of yarding and handling induced probably a lower feed intake which physiological dysfunction resulted in a shortage of Mg within the cattle body. Disington and Tollersud (10) reported that cows reacted actively and very rapidly to lower Mg intake, showing marked decreases in their serum Mg levels within two days.

Levels of serum Mg three days after pasturing indicated that the housed cows (18 mg/L) recovered more quickly than did the cows on pasture (12 mg/L). It might be

surmised that differences between housed and pastured animals were due to differences in the availability of Mg in grass silage and pasture forage. It might also be that the difference was due to Mg intake by the two groups of cows. Other possibilities could be a reluctance of grazing animals to eat the mineral mixture when ample young grass was available or to added stress of pastured animals. Indeed, Allcroft and Green (2) noted that the fall in serum Mg concentration coincided with both the lush spring grass and the change in routine involved in the transfer from barn to pasture. On the other hand, the difference in Mg levels may have been due to salutary effects of housing. Rogers *et al* (17) observed that the incidence of hypomagnesaemia in beef cows was alleviated by housing. Although the cows on pasture appeared to recover by ten days postcalving, hypomagnesaemia was again detected in these animals by the end of the pasture season, a result similar to that reported by Rogers *et al* (15) in Ireland.

Careful daily clinical observations did not reveal any symptoms of hypomagnesaemic tetany or evidence of hyperirritability in the cows, in spite of the very low levels of serum Mg (6 mg/L) in some of them. Hypomagnesaemia without clinical symptoms has been well documented (3,14,15).

At the end of the experiment the Mg concentrations in the bones of the cows put to pasture were significantly lower than those of the cows housed indoors. Blaxter and McGill (6) suggested that bone Mg provides a labile reserve of Mg in young cattle which can be used in the absence of dietary Mg or when there is an increased demand from other tissues. Allcroft (2), on the other hand, observed that Mg in the bone of adult cattle did not provide a readily available reserve.

According to a report from Holland (9), Mg concentration in a random sample of urine gives a good indication of the supply of Mg in the animal. From urine Mg concentration (ppm) the Mg status of cows can be classified as follows:

adequate supply > 100, inadequate supply 20-100 and severely deficient < 20. Similar conclusions were reported by Hungarian workers (22). However, since the present study was intended to assess dietary effects, the two extensive urine samples were taken before the apparent onset of hypomagnesaemia. The levels measured in these samples bear this out, indicating ample supplies of Mg. The results from a limited number of cows however, showed a drastic reduction in Mg levels within three days of the animals being put to pasture. Whether this reflects the decline observed earlier in the Mg levels in the serum or the effects of being put to pasture cannot be ascertained but is a clear indication of the hypomagnesaemic state.

Mg STATUS OF CALVES

Observations on the calves 48 h after birth showed Mg levels to be above 20 mg/L in the serum. By 24 h before pasture the levels had fallen somewhat but they were still generally above 18 mg/L. This decline agrees with the findings of Blaxter *et al* (7) and Blaxter and Sharman (8) who reported a progressive fall in plasma Mg from birth to 100 days. The levels of Mg in the calves dropped considerably immediately after the going to pasture. By ten days postpasture some values were lower than 10 mg/L. It is interesting to note that this drop corresponded to the one observed in the serum of the cows but with a lag of several days, and that, like the cows, the calves housed indoors showed a less marked reduction in Mg levels and recovered more quickly than those outdoors. A possible explanation for this result is suggested by the findings of Blaxter and Sharman (8) who observed a positive association between amounts of Mg in the milk ingested by the calf and its serum Mg concentration.

EFFECT OF RATE OF FERTILIZER APPLICATION

The differences in the rates of recovery from hypomagnesaemia by the cows and calves in the pas-

tures fertilized with 78 kg and 155 kg of N/ha are difficult to explain, especially when samples of the grass from the pastures were not obtained. The lower level of fertilization appeared to lower the Mg content in the animals more than the higher rate of fertilization. This is in contrast to results by Ender *et al* (12). But one should note that there are also reports (20) that in spite of heavy fertilization there were no indications that the application of potash or nitrogenous fertilizer led to the development of hypomagnesaemia. Information generated in the present study cannot obviously resolve this controversy. Critical data on the effects of fertilization are required in order to correlate changes in herbage composition with the incidence of hypomagnesaemia.

EFFECT OF SUPPLEMENTAL Mg

It was recently reiterated (11,14,19) that cattle do not regulate their intake of minerals according to their needs. The intake seems to be related to taste and appetite. Reports from the field have also indicated that flavoring agents, protein and/or carbohydrate materials should be incorporated into mineral feeds to improve their palatability. Rogers and Pool (17) reported that at least 30 g of Mg per day is required to obtain complete control of hypomagnesaemia. It seems likely in the present study that the cows were not consuming enough Mg to prevent the onset of hypomagnesaemia when extra demands for the mineral were imposed upon by stress factors such as prepasture handling, abrupt change in environment, diet, etc.

Chelation and sequestration of minerals to improve their biological availability was in fact one of the attempts proposed to overcome problems arising from suboptimal intake of minerals. However, in the present experiment, insofar as the sequestered Mg used at the low level in the mineral feed is concerned, it was not proven effica-

cious for this intended purpose.

GENERAL SUMMARY AND CONCLUSIONS

Hypomagnesaemia observed in the present study cannot be attributed to pasturing because the onset of the disorder occurred at least 24 h before the cows were put to pasture. Although the actual time of the onset could not be established, it seems possible that the cows at peak lactation may have reacted to stress of prepasture handling. The rate of recovery was related to the method of housing with the cows remaining indoors recovering more quickly. Urine samples from cows returned to spring grass were indicative of low Mg status. In spite of the severe cases of hypomagnesaemia, no instances of grass tetany were observed.

Providing magnesium in the mineral feeds, either as sequestered magnesium or as magnesium oxide, did not prevent or even alleviate hypomagnesaemia.

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